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ABSTRACT

In order to improve physics education some believe that it is necessary to consider teachers' view of quality learning in a specific content context. This report was developed to provide descriptions and comparisons of the conceptions of quality learning held by twelfth grade teachers (n=14) and academics of physics. Results revealed that among the high school teachers was a widespread acceptance of the value of many of the features associated with quality learning (e.g. the importance of integrating and linking for quality learning. A clear exception to this is for the item labeled "students taking responsibility for their own learning." Only six of the fourteen secondary respondents made comments relevant to this issue, and most of these were in the context of experimental work and/or affective dimensions of physics learning. The academics on the other hand expressed views different from those accepted by the study as quality learning. The most collective feature of the views of this group is that they tend to be strongly focused by what their students could not do. The researchers' conception of quality learning was, implicitly, rejected as being beyond the current abilities of students. (ZWH)

# CONCEPTIONS OF QUALITY LEARNING

# HELD BY HIGH SCHOOL AND UNIVERSITY PHYSICS TEACHERS

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## INTRODUCTION

We report here the results of a study of the conceptions of quality learning held by two samples of physics teachers in Victoria: one sample was drawn from Grade 12 (final year) high school teachers, the other sample from academics teaching first year university physics. The essential purpose of the study was to provide descriptions of the conceptions of the two groups, and to compare these. The place of this paper in this symposium is to consider the nature of these conceptions from everyday classrooms, secondary and tertiary, in terms of the view of quality learning on which the symposium is based.

We begin by elaborating the reasons for considering teachers' view of quality learning in a specific content context. Then we indicate the reasons for exploring secondary and tertiary teachers' views, describe the methodology used, and detail some of our findings.

## PHYSICS AS THE CONTENT FOCUS FOR THE STUDY

There are two broad issues underlying our decision to investigate teachers' conceptions of quality learning in a specific content context, rather than in a more generalized way. The first issue is the importance of enhanced metacognition in our own view of quality learning, the view elaborated by White (1994) in this symposium. One cannot foster enhanced metacognition in some content-free approach; in order for learners to accept the importance of enhanced metacognition they need to experience this importance in the context of real learning tasks (see, for example, Baird & Northfield, 1992; Gunstone & Baird, 1988). That is, we assert that to consider metacognition and quality learning one must also consider the content which is being learned.

The second issue influencing our belief that this study needed to be embedded in specific content has been referred to in the introduction to this symposium - while "quality" is a term used today in a wide variety of contexts, many of which have significant political dimensions, it is used with an extraordinarily diverse range of meanings. Indeed, as we found in an extensive review of curriculum documents (Macleod et al., 1991), "quality" is often used in ways for which the meaning intended by the writers of these documents is totally obscure. It is even plausible that some documents have used "quality" with no sense of a meaning for the term. Given this, we believed it was important to avoid direct use of the term "quality" in our probing of teachers' conceptions and to instead use more indirect methods which required a content context. (We also were concerned that solely and directly asking about "quality learning" would precipitate responses focussing on issues other than view of quality student learning - facilities available, issues in selection for university courses, school retention rates, reductions in funding, etc.)

Our own teaching and research interests meant that science was the obvious content context for us to use. However our desire to explore views of tertiary as well as secondary teachers (for reasons outlined in the next section) required us to be more constrained than this. A specialist science was needed, and therefore specialist (i.e. senior) high school teachers. We focussed on physics and physics teachers for a number of reasons. One of these reasons relates to a particular issue within Victoria and its schools. The other reasons are more general. The most obvious of these is the diversity of views about the appropriate focus for physics education likely to be found among any group of physics teachers - crudely, conceptual versus mathematical approaches. This dichotomy may well be artificial, but the greater prominence of this

in debates in physics education, relative to other sciences, made physics an obvious choice among the sciences for our first attempts to probe conceptions of quality learning. In addition, research on the learning of physics concepts has been more prolific than for other sciences. This means, in general terms, more is known about the learning of specific content in physics and there is a wider variety of existing learning tasks and questions. (Questions were needed for our research approach; see below.)

The reason specific to Victoria for choosing physics was the recent major curriculum reform at Grades 11 and 12 - the introduction of a new structure known as the Victorian Certificate of Education (VCE), and new curricula within that structure. Space precludes any discussion here of the nature of this significant change (see, for example, Northfield & Winter, 1993). However it was a change that generated substantial public debate, including by politicians and university academics, and with extensive exposure in the daily electronic and print media. These debates revealed a variety of strong opinions, frequently expressed with phrases like "maintaining standards", "ensuring quality", and "access and success". It was often very clear that secondary and tertiary eductors did not share common meanings for these phrases. All grade 11 and 12 science subjects underwent major curriculum change in the introduction of VCE, and hence, from this perspective, all would have been interesting content context for this study. Physics however had a particular addition characteristic: two of the three writers responsible for the new curriculum had views of learning with considerable similarity with that argued by White (1994) in this symposium. Both were physics teachers with a highly informed commitment to

constructivist views of learning, and to classroom practice which reflected constructivist learning.

Our methodology involved the use of a variety of physics questions which could be given to students. It was important that these involve content familiar to interviewees as we intended to ask for judgements about the student learning involved in answering these questions. Therefore we used the area of mechanics as our specific content context. All teachers who participated in the study, as we expected, had taught mechanics and had studied mechanics. This was an obvious consequence of the central place occupied by mechanics in secondary and tertiary curricula for many years.

## THE SAMPLE: SECONDARY AND TERTIARY TEACHERS

The long and emotive debate about the new VCE, as referred to above, was frequently characterized by clear and public differences in the views of secondary and tertiary educators (albeit often views of vague and ill-defined notions like "quality" and "standards"). This was our motivation for including both secondary and tertiary academics in our study.

The secondary sample comprised all teachers of Grade 12 physics in a Victorian provincial centre (n = 14). This gave us a mix of young and experienced, government and private schools, teachers who were the only physics teacher in the school and those working with one or two physics colleagues. The tertiary sample comprised academics involved in teaching first year physics at Victoria's two largest universities (Monash and University of Melbourne; both are government-funded, there are no private universities in Victoria). All 14 such academics were approached. One of these was overseas throughout the study. The remaining 13 all agreed to be involved.

## METHODOLOGY

Our focus was on an exploration of the different ways individuals conceptualize "quality learning" in physics. We were not at all concerned with variables which might have contributed to these differences. Our research then reflects aspects of phenomenography (Marton, 1981).

We used a modified form of the "interview-about-instances" (Gilbert, Watts & Osborne, 1985; Osborne & Gilbert, 1979). As originally conceived, this approach involves giving interviewees separately a number of instances and non-instances of a particular concept, usually in line-drawing format, and basing an interview around these. We used a series of physics questions in the same way, and asked interviewees if each question focussed on any "aspects of learning worth fostering". We have noted above our reasons for avoiding the explicit use of the term "quality learning".

For such an approach we needed a variety of question forms. We began by each generating examples of questions we would individually label "good" or "bad" in terms of the learning it would foster, and also by having another science educator at Monash undertake this task. We then collectively assembled a group of questions which we saw as representing a wide diversity of forms of learning, and which we believed would not be of such an unfamiliar format that interviewees could not see the intent of the question. (This last point we judged to exclude, for example, a "fortune line" question; see White & Gunstone, 1992.) The group of questions was then trialled in individual interviewees with a small number of high school physics teachers from Melbourne and a final selection of 12 questions was chosen. The 12 questions are shown in Appendix 1. They include questions taken directly from other sources (e.g. Qn L, from Walker, 1977), questions devised from ideas in other sources

(e.g. Qn F, which is adapted from student laboratory exercise), questions we had previously generated for our own teaching purposes (e.g. Qn B), and questions we created for this study (e.g. Qn A). The order of the 12 questions, A-L, was randomly determined.

For the interviews for the study proper, each question was reproduced on a separate 15cm x 20cm card. The interview began by asking the teacher to imagine "your ideal senior secondary physics classroom" (or, for the university sample, "your ideal first year tertiary physics class"), and to consider "ideal" in terms of student learning. For each of the questions in order, the teacher was asked "If the students in your ideal class could answer this question would that demonstrate that they had developed any aspect of physics learning that you would want to foster." Specific further probing occurred as appropriate to explore the meaning of some responses, including elaborations of issues raised by interviewees. We recognized that our selection of questions could not represent the universe of perceived desirable learning outcomes. When all 12 questions had been explored, interviewees were asked to "rank the questions according to the quality of physics learning that you feel they demonstrate." This process was then explored. Then, interviewees were asked to locate the two questions at the extremes of their ranking on a continuum labelled "absolutely terrific" to "utterly useless". If the respondent did not place his/her extreme questions at the ends of the continuum the interviewer probed perceptions of questions which would be at the ends of the continuum. Finally, the interviewer asked if there were "any types of questions you feel I have omitted", and probed any response. The full interview schedule (tertiary version-differs only in the description of teaching context, as already noted) is shown in Appendix 2. A brief extract from

one secondary interview is shown in Appendix 3 in order to give some sense of the way interviews proceeded. All interviews were conducted by the second author of this paper.

## ANALYSIS OF DATA

Each interview was transcribed and the transcripts inspected for clear indications of aspects of physics learning which were valued by each interviewee. A list of these was generated. A few examples of the issues on the resulting list are "being able to represent and analyze data graphically and mathematically", "making connections between related things", "looking critically at question answers to se if they are realistic - particularly if they are numbers", "thinking in terms of all the factors involved". The transcripts were then reanalyzed for negative as well as positive comment on each of the issues on the list.

## RESULTS

As with all such interview studies we have generated a considerable quantity of data, with individual conceptions of quality learning showing considerable variation. Our approach to presenting some sense of these data here is, in line with the place of the paper in this symposium, to take four of the issues from the list described in the Analysis of Data section and consider the trends in secondary and tertiary responses for each. The four issues are all ones which were significant in the interview responses (i.e. a number of respondents raised the issue, and the issue emerged in a number of different problem contexts), and also are issues of relevance to the conception of quality learning on which this symposium is based. We elaborate this latter point before discussing the data.

Our four issues are "Doing experimental/practical work", "Linking physics to 'the real world'", "Students taking responsibility for their own learning", "Being confident/being proud of what you can do". The first of these (experimental work) has links to the conception of quality learning through specific responses and because experimental work was seen as a central aspect of physics learning worth fostering by many respondents. The second issue (liking to real world) relates to quality learning being seen to involve integration and linking, consideration of knowledge in relation to oneself and one's place in the world, knowledge which is usable and active. "Students taking responsibility for their own learning" involves commitment, purpose for learning, and knowledge in relation to oneself. "Being confident ..." is a significant aspect of the emotive component of quality learning.

Summaries of the data relevant to each of these issues are now given. Respondents who are quoted are designated S.1 - S.14 (secondary respondents), T.1 - T.13 (tertiary respondents).

Doing experimental/practical work

Both the secondary and tertiary groups commonly described experimental/practical work as an aspect of physics learning worth fostering. However beneath this simple observation there were significant differences between the two groups. The secondary group put far more emphasis on this issue; most of them mentioned the value of experimental work several times and half (7) ranked it as "absolutely terrific". For them, "doing experiments or practicals" was taken to include both designing and actually doing relevant investigations/experiments. While three of the tertiary group mentioned the value of students doing experiments themselves, only one respondent emphasized its importance. Other tertiary

respondents placed more emphasis on developing skills in designing experiments or in criticising procedures, but ranked even this less highly than did the secondary group.

The secondary respondents' reasons for valuing experimental work (both designing and doing) were all related to the contribution they saw it making to student learning. Many comments referred to its value in developing "real understanding" (as distinct from "regurgitation"), in fostering an analysis of all factors involved and a consideration of parameters and limitations (as distinct from concentration on getting a correct answer), in promoting students taking responsibility for their own learning, in building on one's own experiences, and in using a wide variety of ideas and approaches. Not only did they see experimental work (designing and doing) as contributing to these different aspects of learning worth fostering, they saw many of these aspects as interconnected and mutually dependent. A number of the above points are illustrated in the following examples of quotes.

> It (experimental work) requires real understanding and using a wide range of approach skills and ways of thinking. (S.5)

> Seeing things happen makes abstract concepts more real which helps students develop their understanding. It involves the kids doing things, they have to really understand what they are doing to make something work, and it is relevant for them when they are actually doing it, also it involves many different skills and aspects of learning. (S.2)

> It involves students thinking for themselves, bringing their own thinking to the situation and building on that, also students doing things themselves leads to more interest and motivation. (S.6)

> Students become responsible for their own learning, they realise that you don't need to get a 'right' answer to learn, and, setting parameters and realising limitations helps you to learn about physics and about the real world. (S.1)

> It is good to use results of experiments to reinforce the theory, also it provides the opportunity to consider parameters and limitations. Explaining results involves expressing your ideas, this is of greater value in terms of learning then getting a right answer. (S.8)

> Students have the satisfaction of doing things themselves and are more likely to remember something they enjoy doing. Also, it involves practical skills, using equipment, etc., which are not developed in other subjects. (S.7)

As already noted, three of the tertiary group saw value in students doing practical work, but only one emphasized its importance. He did so in terms of student learning, but in affective not cognitive terms: "It would be fun, they would enjoy doing it which is crucial for physics learning" (T.13). Another (T.2) did suggest that if students actually understood the experiment outlined in Qn D then this would help their understanding of concepts involved, but in all his other comments he placed far more emphasis on experimental design. So did eight other tertiary respondents.

The value placed on experimental design (as distinct from experimental activity) was because of the tertiary group valuing this as an accepted part of science, or as part of the repertoire of an experimental scientist. For example:

> (s)ince a lot of physics is experimental and has to be planned I suppose it has some virtue. It is appropriate conditioning for the techniques of an experimental science. (T.2, in response to Qn F)

Several comments indicated that the tertiary respondents who did not mention 'doing experimental work' as something worth fostering saw the present laboratory based practicals that students do as necessary because 'experimental work is part of being a scientist'. One specifically advocated skills in experimental design to increase the effectiveness of the students when they 'become scientists' in the future, not because it would change their learning at present.

> It involves experimental design which is often neglected as an aspect of prac. classes. When they (the students) become a research assistant or graduate and are asked to measure something they do it on the basis of what they have seen, rather than think about the possible ways of doing it. (T.4, in response to Qn D)

Two comments showed that when respondents used the term 'experimental design' this did not necessarily mean that they valued students designing experiments themselves. Rather it meant that being able to criticize experimental designs or procedures is a necessary skill for scientists to have so that they can identify errors in methods used, or conclusions drawn. One tertiary respondent felt strongly that although this is implicit in science, the clear thinking and use of reasoning involved 'is part of life not just physics' and is more properly taught in other courses such as English.

Another respondent felt that an appreciation of experimental design is extremely valuable because it helps bridge the gap between theoretical and experimental physicists. He believed many students are more interested in the theoretical aspects of physics and making them think about the challenges of designing experiments would broaden their perspective; it would make them appreciate more the initiative needed and struggle involved in getting the numbers about which they theorise. He also thought that an appreciation of experimental design is required for many careers (T.9).

All of these comments indicate that, unlike the secondary group, most of the tertiary respondents valued experimental work for reasons other than its contribution to the learning of physics by the students. One tertiary respondent held almost the opposite view: that the students were not capable of designing experiments or criticising procedures until they know far more about physics phenomena than they do in first year. Commenting on Qn D he said:

> Subtlety of criticizing experimental design is not something we expect of first year students, most have enough difficulty drawing conclusions from 'set' pracs. In first year our job is to amaze them with the most exciting demonstrations we can find and get them to put forward the hypotheses; working the other way is too hard, they don't have the experience of basic phenomena on which to base their experimental design. We should not take away the wonder and magic by confronting them with tasks they are not ready for. (T.11)

This last comment is particularly interesting in the Victorian context. One of the three externally set assessments for Grade 12 physics in this state is an "Extended Practical Investigation". This requires students to devise, carry out and report on an extended investigation, crudely to do that which respondent T.11 asserted was beyond first year university students. The Grade 12 assessment dimensions of extended practical investigations (EPI's) may be the origins of another secondary/tertiary difference linked to practical work, a difference also related to the view of respondent T.11 (above). That is that the secondary group generally had a very broad view of the value of an EPI - these were seen as very valuable assessment tools in terms of allowing students to display their understandings (and be ranked accordingly if necessary), but, in addition, it was also seen as an assessment tool which played a major role in the development of the range of understandings it assesses. In other words, the secondary group saw the EPI as itself a promotion of valuable learning. The tertiary group, on the other hand, had much more restricted views of assessment, including practical exams, tasks, etc. - these existed to allow students to show what they know.

<u>Linking physics to 'the real world'</u>

Linking physics to 'reality' or to 'the real world' was an aspect of physics learning considered worth fostering by both groups. However, their comments on various questions show that the meaning they attach to the phrase 'the real world'

differs. The tertiary group considered that situations, such as the problems faced by airport planners (Qn A), or car drivers (Qn L), or riding a bicycle (Qn B and Qn D) involved linking physics to the real world but most of them did not make any distinctions between these questions in that respect. The secondary group, however, while also valuing situations like Qn A, which link physics to everyday life and society in general, made a distinction between that and situations like Qn D which link physics concepts to the students' own lives and experiences in particular. Most (12) of the secondary respondents emphasised the value of this; only three of the tertiary group mentioned it at all, and only one of those emphasised its importance.

Both groups saw linking physics concepts to the real world, as they described it, as worth fostering because this underlines the relevance of physics and so increases the students' interest in the subject and their enjoyment of it. Also, linking physics to situations outside the laboratory involves the students in questioning how and why situations occur in nature and so develops their sense of wonder, and their enthusiasm for physics as a way of extending their knowledge.

Many of the tertiary group valued linking physics to the real world in terms of affective aspects of learning, such as those mentioned above, rather than in cognitive terms. T.4 and T.9 were exceptions to this.

Respondent T.9 was critical of Qn H (the concept map) because "it relates to nothing real". He saw such questions as "concerned with the formal aspects of physics rather than with students making their own understanding of concepts". Other members of the tertiary group saw linking with the real world as important in demonstrating understanding of concepts, not in developing that understanding. This view had its origins in a belief in the value of teaching physics, initially, in the abstract.

T.13: We teach it [physics] in the abstract, being able to go from the abstract to the concrete shows understanding of the abstract.

Interviewer: Why do you teach it in the abstract?

T.13: It is more efficient, in one go you can learn about bicycles, aeroplanes, go carts, rockets; any thing that moves, and you can then apply it to your own situation. It would be very difficult - very often [to teach it from real world examples] - that is what is wrong with the real world; it is too complicated, too difficult.

Overall, T.13 thought that relating physics to real world situations makes it a lot more fun - which he saw as crucial for physics learning - and would demonstrate understanding of abstract concepts. However, the complexity of the real world makes understanding difficult and so he would not teach physics concepts by starting with concrete examples of their occurrence in everyday situations.

A number of respondents argued similarly, often with harsh reference to the VCE (Grade 12) Physics course. (This course explicitly places physics in contexts, and strongly reflects a philosophy of beginning with the concrete, with reality and then moving to the abstract.)

> There is another world which is also part of nature which we do not experience in everyday life, but wonder (at that world) has vanished from school physics...the people who put VCE together have a very instrumentalist view of the world, very practical: wonder, inner space, outer space, the cosmos is not part of what is in their minds and this is reflected in school physics. It is a political thing, it views physics in a utilitarian way which I do not agree with. Physics also has a great cultural value, and has a great deal of culture that is transferable to other areas which is underestimated. It is the paradigm of an exact science; in the VCE science has gone, the subject has been destructed. (T.7)

None of the secondary group, nor any of those who developed the VCE physics course, see this view as reasonable. However other tertiary respondents expressed similar sentiments, for example T.5 who was particularly concerned with the structure of the discipline of physics being quite at odds with a context based

approach, and T.2 who shared both these broad views. T.2 also argued that putting physics into a practical context can disadvantage brighter students because they think more about all of the factors involved and worry more about the assumptions that have to be made than less bright students. This view is reflected in several tertiary group comments on the physics questions we discussed; they were unhappy about using several of the questions as assessment items for this reason. All but T.4 seemed to view 'good' assessment items as those allowing bright students to display their store of knowledge, or to reveal the understandings they have, rather than those which challenged the students' thinking. For their purposes, good assessment questions would be likely to concentrate on a limited number of factors and have many assumptions stated. The secondary group placed far more emphasis on the value of questions which required the students to 'analyse all the reality' in a given situation and so have their thinking challenged. This difference between the groups is a reflection of the tertiary group tendency to view 'assessment' and 'learning' as separate processes, while the secondary group's comments indicated a belief that assessment can play a dual role: provide the students with the opportunity to display their understanding and also help develop that understanding.

None of the secondary respondents shared any of the tertiary group reservations about teaching physics by linking physics concepts to the real world, even right from the start of a topic or concept. All considered this as an aspect of physics learning worth fostering and twelve placed particular emphasis on the value of linking physics concepts to the 'real world' of the students, that is to the students' own experiences. They were convinced that this is vital, not only to stimulate the students' interest and motivation but also to provide student understanding of physics concepts.

This was so self evident to some respondents that they appeared non-plussed that someone should ask them why they thought this was so. Their comments show that they considered linking physics to 'the real world' as important in itself and also critical in the way it interconnects with many other aspects of physics learning. We give just a few of a very large number of examples of this strength of belief.

In considering Qn E (ballistic pendulum), respondent S.4 observed that "it serves no real purpose for the students, it is not related to the real world for them". He saw this question as detrimental to student learning, not only because it would not stimulate student interest but also because it would encourage students to think only of getting the correct answer. "They would not see any beauty in it unless they were pure mathematicians. Students not getting the right answer would tend to think 'my God why aren't I thinking like them'." He saw contrasting positives in Qn D.

> This sort of question could give some opportunity to follow things through until it is sorted out in your mind, rather than just find out something specific that someone has set you to do and then stop. (S.4)

Similar views were expressed by S.3. Qn D, for example, was seen by this respondent to be a very good question because "when students read it they would think of themselves going down the hill on a bicycle". This would increase student motivation to think about what is involved in the situation.

In addition to broadening the students' horizons beyond being content with getting the right answer to questions that have been posed by someone else, S.3 and S.4 also thought that linking physics to the students' own experiences would help to make the physics concepts more concrete, or less abstract, for the students and so help develop their willingness to ask questions for themselves and think more deeply. These views were shared by several other secondary respondents. For example:

> Examples from everyday life lead them to question what they see and ask why. Because they have seen it, it is concrete for them and they want to explain it. Starting with what you know or have seen gives you the confidence to go on to what you don't know. (S.14)

> Many students cannot get a mental picture from words on a page, seeing a physical representation helps them to see the picture better. (S.9)

> When students are thinking of physics in terms of their own lives, their own experiences, that is when they are really learning. (S.8)

S.9 also thought that 'analysing all the reality' in real life situation was important because it is more interesting for the students and so can be used to lead them into thinking about more abstract ideas. This also involves people in physics, thus overcoming the idea in many students' minds that physics has nothing to do with people. She thought that studying real situations is important for the students' understanding. If they do not study real situations students do not realise that physics, as they study it in 'ideal' situations, and the real world are related. Consequently they resort to intuitive rather than Newtonian ideas to explain situations that occur in real-life.

A number of other positive consequences of seeking to link to the real world were argued by secondary respondents: students being challenged to question everything around them; considering situations where many factors need to be addressed; thinking about nature, which is "brimming with information" (S.12); using exploration of links to generate interaction, discussion, exchange of ideas among students; foster understanding by making the abstract more concrete; develop students' sense of wonder.

Not one of the secondary group shared any of the tertiary reservations about teaching and learning physics by linking concepts with relevant real-life situations.

The value seen in this by the secondary group went far beyond the affective advantages generally seen by tertiary respondents. Only two tertiary respondents (T.4 and T.9) saw value in this in terms of developing conceptual understanding. Four others (T.2, T.6, T.10, T.13) who saw that appropriate application of concepts to real world was in demonstrating understanding also saw beginning with the real world as detrimental to understanding.

Students taking responsibility for their own learning

Six of the secondary respondents commented on the value of students taking responsibility for their own learning. For one (S.1) this meant students developing clear understandings of what they are doing by taking control of how they do it. Using a format like Qn F when the students are doing practical work, rather than giving them a list of instructions to follow step by step, is an example of how S.1 sees this being facilitated.

S.4 expressed a similar view more strongly when he said about Qn F:

> It would be the first stage in loosening up the teacher's control over how the students do an activity, first stage in students seeing it as being under their control.

S.2 favoured students becoming responsible for what they do as well as how they do it. He saw student centred experimental investigations as an ideal way of facilitating this since it requires students to decide on what questions they want to ask as well as how to go about finding answers. This is very important because the process involved leads to students to the realisation that "you don't need to get a right answer to learn". S.4 strongly agreed with this, and also said that it helps students to come to the realisation that, in developing knowledge and understanding, being able to ask appropriate questions is an important skill. He thought that questions like Qn

B would facilitate this - it focuses on asking questions rather than getting a 'required' answer. He was very critical of questions like Qn C because of the requirement to reproduce someone else's definition.

S.9 valued students following their own way of doing things because this leads to excitement and interest for students. It also gives the teacher access to valuable questions and approaches arising from the students' interests, questions and approaches which the teacher could not otherwise have. S.14, in commenting on Qn B, made the same point.

> It would allow them to come up with questions other than those the teacher has in mind, this lets the students know that what they think is important and encourages them to bring forward their own ideas.

Later in the interview he elaborated this view.

> It is important that the students realise that the teacher is not the oracle passing knowledge to them. It is important that they get enjoyment and stimulation from things that happen and ask questions themselves. Establishing a relationship where students and teachers interact and work together is very important for learning to take place. It is important for students to realise that their ideas are valued and worthwhile.

Only three of the tertiary group made any form of reference to this issue, and one of those was a strongly negative comment precipitated by Qn A.

> It is too indefinite, requires too much initiative which first year students don't have. We don't have time to foster this and teach them the physics we think is essential. We are not really testing with those who can think independently in mind in first year, (we) are trying to bring them all up to the same standard. (T.13)

The other two comments were very specific and single. T.12 once indicated a view that students need to develop their own ways of learning physics, in terms of needing to think about the physics involved in a situation rather than relying on lists of formulas provided by their lecturers. T. 4 thought that questions like Qn K should be

more commonly used because "the students' ideas are challenged and this helps the students to realize that they have to put in an effort for themselves if they are to understand".

Being confident/feeling proud of what you can do

Eleven of the secondary group regarded feeling proud of what you can do and having the confidence to try new or more challenging tasks as an important aspect of learning. For example, S.5 and S.13 commented on the value to students of questions or tasks which they can do - feeling good about being able to do the relatively easy tasks gives them the confidence to try more challenging tasks or questions. S.14 expressed a similar opinion and said 'starting with what you know or have seen gives you the confidence to go on to what you don't know'.

S.8 thought that questions like Qn D are particularly good because they boost the students' confidence in their ability to improve on someone else's design; students realise that they too are capable, and both their confidence and their ability improve with practice.

> If they are not used to that kind of question they tend to run away from them and feel more comfortable with just memorising even if it does not engage their interest. (S.8)

Further to this S.3 said that he thought the brighter students have their confidence in themselves affirmed by being 'right' and so they enjoy getting the right answer even if the question is boring. Weaker students, who do not feel confident anyway, are more likely to ask 'why am I doing this, it's boring'. Therefore, S.3 thinks, some of the brighter students would feel happy doing questions like C which do not require understanding and are not 'connected to reality'. Weaker students would not be interested unless they could see the relevance of the question.

S.4 felt strongly that feeling confident in your own ability to do things and to develop your understandings is a vital part of physics learning. Students need to realise that "learning is something we can all do in our own way, and [is] not done in a prescribed way by a select group". For this reason he was critical of using jargon rather than the students' own words to describe concepts. Commenting on Qn C he said:

> You could regurgitate definitions without understanding, also, if you hear people using the jargon it makes you feel that you can't comprehend what they are talking about, they are an elite and you butt out of the conversation.

S.14 stressed the importance to learning of students realising that their ideas are valued and worthwhile. S.9 and S.12 emphasised the need for students, particularly girls, to become comfortable with learning physics and confident in their own ability to do so. The use of girls' as well as boys' names in physics questions facilitates this because it includes girls/women as people for whom physics is relevant and so 'helps women to develop self esteem in science'. (S.12)

S.9 thought that building up the students' confidence is important for learning in general but is particularly important in physics because the subject is considered difficult.

None of the tertiary group made any reference to 'building self esteem' or 'not feeling too at risk' in relation to learning. Any comments that they made about building student confidence were in the context of the students' performance in exam situations. When commenting on Qn C T.9 said:

> Although it involves no more than rote learning really [it] would give the students a bit of confidence, they would easily get a few marks for defining things.

When discussing Qn G T.10 noted that although it is very elementary it might be used as a lead in question "to get students warmed up in the exam". T.12 made a similar comment about Qn D, adding that "it would give some confidence to the weaker students".

## CONCLUSION

These data point to clear differences in the conceptions of quality learning held by the two samples. Of course there is also variation within each sample, but general trends seem obvious to us.

These trends are not an artifact of our sampling of issues derived from the interviews for consideration in this paper. Similar trends exist for the other issues we identified which have not been described here.

For the secondary group there is a widespread acceptance of the value of many of the features of our conception of quality learning, with this acceptance often being an informed one. That is, the acceptance of, for example, the importance of integrating and linking for quality learning by the secondary group is often accompanied by a sense of why these are important. The one clear exception to this is for the aspects of our conception of quality learning embraced by the issue which we labelled "Students taking responsibility for their own learning". Only 6 of the 14 secondary respondents made comments relevant to this issue, and most of these were in the context of experimental work and/or affective dimensions of physics learning. Our notion of students' understanding and controlling their own learning in order to, inter alia, develop deeper cognitive understanding was rarely raised; when it was it was by tangential, even vague, reference.

The tertiary group expressed views with relation to our conception much more rarely, and those views which did emerge were much less informed than for the secondary group. Indeed the most obvious collective feature of the views of the tertiary group is that they expressed a deficit view of learning - they tended to be strongly focussed by what they saw their students could not do. Our conception of quality learning was, implicitly, rejected as being beyond the current abilities of students. These teachers' views of the nature of physics were often more influential on their views of quality learning than was any knowledge of their students.

This dissonance between secondary and tertiary views of "aspects of physics learning worth fostering" is disturbing. A justified simple summary of many aspects of the dissonance would be that secondary physics teachers spend considerable energy in fostering appropriate student approaches and abilities; tertiary physics teachers then assert that these same students in the following year are incapable of using these approaches and do not have these abilities. A broadly similar statement might well be made about students moving from the final year of primary (elementary) school to first year high school. However the suggestion in our data that any form of coherent conception of learning is not common among our tertiary teacher sample suggests this problem is more serious at the educational levels on which this study has focussed. Quite what tertiary physics students make of this dissonance is unclear. Research in progress at Monash with first year physics students may help.

The positive finding from this study is that the conception of quality learning on which this symposium is based is, broadly, not at odds with the conceptions of our high school teacher sample. Our conception is broader, particularly in the centrality we give to purposeful, reflective learning. However this is an extension to teacher

conceptions, not a restructuring of them. In our attempts to consider teacher education, teacher development, classroom learning and assessment in our schools in the terms described by White in this symposium we do not appear to be out of step with, at least, high school physics teaching and learning.

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APPENDIX 1: Questions used in interview

Question A

Consider the following physics problem:

"A planner is working on the preliminary design of a new community and wonders if there is sufficient space for an airport for small planes. The planner can allow 100 m for the length of the runway for the airport. One type of aeroplane which would use the airport must reach a speed of 200 km/hr (55.6 m/s) in order to take off. Will this aeroplane be able to use the planned runway?"

What extra physics information do you need to solve the problem?

Question B

1. Write a physics question for which an appropriate answer is

   "Because there is friction between the tyres of the bicycle and the road."

2. Write 3 other physics questions for which this same answer is appropriate.

Question C

Define the physics terms 'work' and 'power'. Name and define the SI unit of power.

Question D

Mary and Jane wanted to do a test to find out which of their bicycles was the faster. This is what they did:

1. They marked out a starting line at the top of a hill.
2. They put the front wheels of their bicycles on the starting line and sat on the saddles.
3. They both made five complete turns of the pedals and then sat still on their bicycles.
4. They noted which bicycle crossed the finishing line first.

   (a) What they did was not a fair test. Suggest two reasons for this.

   ______________________________

   ______________________________

   ______________________________

   (b) Suggest one change which would make the test more fair.

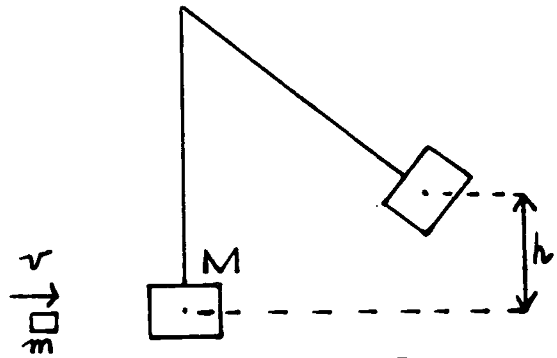
   ______________________________

   ______________________________

   ______________________________

Question E

The speed of a bullet, mass m, can be measured by use of a ballistic pendulum. The bullet is fired into the pendulum bob, mass M, and is embedded in the bob. The pendulum bob swings to a maximum height h.




Show that the velocity of the bullet is given by $v = \sqrt{\dfrac{2gh(M + m)}{m}}$

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Question F

The following experiment illustrates that a raised weight has the capacity to do work by virtue of its potential energy. The steps involved, A to E, are not in an appropriate order. Re-arrange them so that they could be followed by someone doing the experiment.

A. Pull the cord at A until the 100g weight is raised 50cm above the bench top;

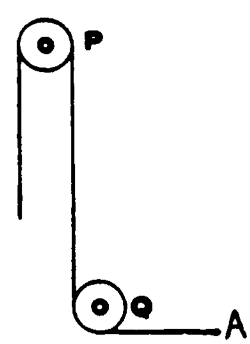
B. The potential energy of the raised weight is expended in doing the work of moving the truck;

C. Tie the end A of the cord to a toy truck;

D. Drive two nails into a vertical board and support two small pulleys P and Q from the nails;

E. As the weight falls the toy truck moves;

F. Tie a long cord to a 100g weight and pass the cord over the pulleys as shown in the diagram

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Question G

A car starts from rest and is accelerated uniformly at the rate of $2 m/s^2$ for 6 seconds. It then maintains a constant speed for half a minute. Find the maximum speed reached in km/h and the total distance travelled in metres.

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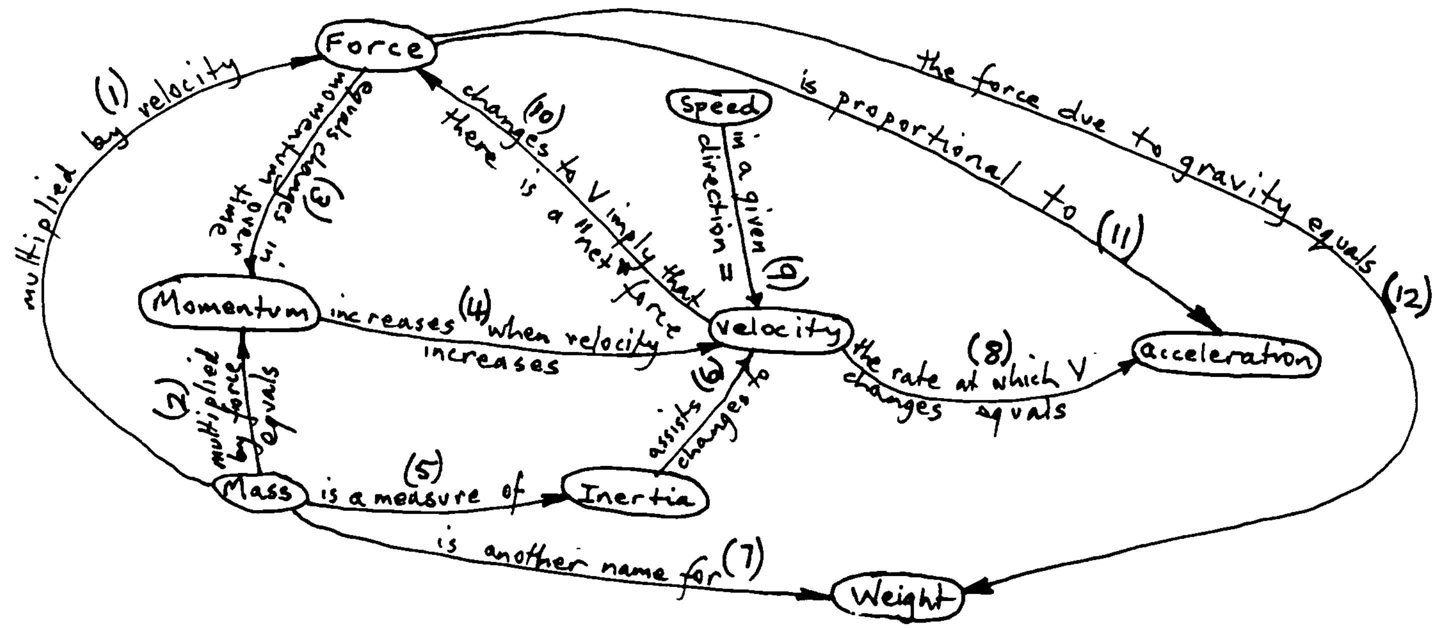
## Question H

A physics student drew the following concept map to explain how various terms in physics are related.

Indicate which of the physics statements 1 to 12 are correct. For each statement that you identify as incorrect substitute a correct physics statement.



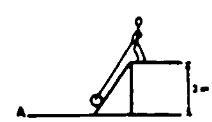

## Question I

The pictures show a man raising a heavy roller from one level to another using a rope to pull it up different planks.

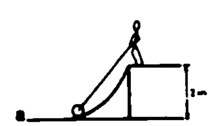
The statements below are about the amount of energy he uses in each case.

A) Put a tick in the box beside one statement you agree with.

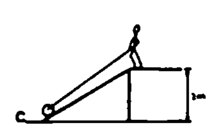
☐ **A** The energy he uses to lift the roller on plank A is least.



☐ **B** The energy he uses to lift the roller on plank B is least



☐ **C** The energy he uses to lift the roller on plank C is least



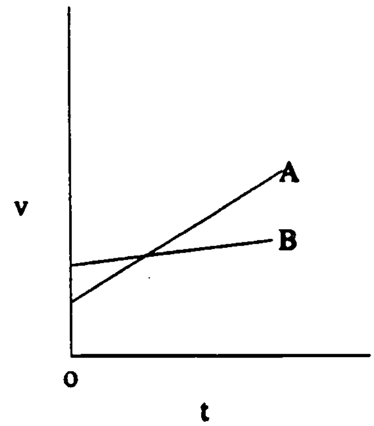
☐ **D** The energy he uses to lift the roller is the same which ever plank is used

b) Give the reason for your choice of answer:

______________________________

______________________________

Question J




Two cars go past the same point at time 0.

- Which car is going faster at 0?
- Which car is accelerating more?
- Mark the time at which they are going at the same speed.
- Mark the time after 0 at which they have gone the same distance.

Question K

"Energy is the capacity to do work."

Comment on the adequacy of this definition for phenomena in physics.

Question L

Suppose you suddenly find yourself driving toward a brick wall on the far side of a T-intersection (Figure 1). What should you do? Use your brakes *fully*, without skidding, while steering straight ahead? Turn at full speed? Or, turn while applying your brakes as well as you can?

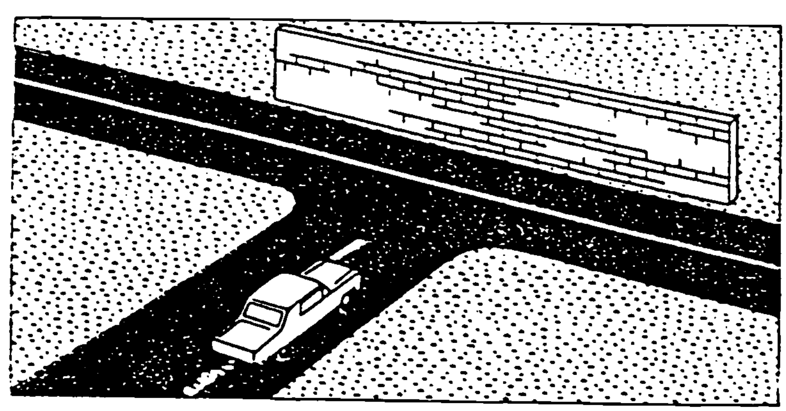


*Figure 1*

APPENDIX 2: Interview protocol (tertiary)

Part 1: "I would like you to imagine your ideal first-year tertiary physics class - that is ideal in terms of the learning of physics by the students. I have here a number of physics questions, for each question I would like you to tell me: if the students in your ideal class could answer this question would that demonstrate that they had developed any aspect of physics learning that you would want to foster."

Place Qn A in front of respondent. When respondent's views have been explored, repeat with Qns B to L. Repeat "if the students in your ideal class ... that you would want to foster" for each new question.

Part 2: When the respondents have answered Part 1 for each question, A to L, ask them
"can you rank these questions according to the quality of physics learning that you feel they demonstrate?"

Part 3: Then ask "did you have any difficulty in ranking the questions?" and probe as appropriate.

Part 4: If respondent has given some questions the same rank ask "why did you decide to rank the questions in this group equally?"
(Check in particular if they have given the questions the same rank because they are different types of questions but of equal importance in terms of the type of physics learning involved, or because they are the same type of question in terms of the type of physics learning involved.)

Part 5: Ask "do you see these questions, or some of them, as being about different types of learning?"

Part 6: Place continuum in front of respondent.

absolutely terrific ———————————————— utterly useless

Ask "where on the continuum from 'absolutely terrific' to 'utterly useless' would you place the questions at the extremes of your rank order in terms of the physics learning they demonstrate?"

Part 7: If there are gaps at the ends of the continuum ask "what type of question would you put in that position?"

Part 8: Ask "are there any types of question that you feel I have omitted?" and explore any response.

Part 9: If there is a response to Part 8, ask "where on the continuum would you place that type of question in terms of the physics learning in demonstrates?"

APPENDIX 3: An extract from a secondary interview

I: Yes. So O.K. That's Question A. Question B - same thing - if they could answer that would that demonstrate that they had developed any aspect of physics learning that you would like to foster?

R: Writing a question for an answer they can write just about anything and it may or may not develop physics. They could word a question that had nothing to do with physics for that, I think is too vague, unless they were being guided.

I: Yes. So if you asked them to say write a physics question O.K. and if they could do that regardless of the fact of the vagueness, if they could write a satisfactory physics question, would that involve valuable learning?

R: The definition of physics to them. I mean I know what question I want them to ask, but I doubt they would. I think they would have a great deal of fun with that but I don't know that they'd do much physics. I don't know what they'd do. I'd have to try it on them. I'd love to try that one on them actually.

I: What would you consider a reasonable physics sort of question? What sort of things would you think were acceptable?

I: I like open questions which is why I'd only use Question A as an introductory one because I like open questions. So I like the idea of that; I wouldn't use if for an assessment question though, but I don't like them writing the question for an answer because I've found when I've tried that they start all sorts of weirdo things which may or may not be good. I'd like to try it but it's not that it's open. I really like open questions.

I: Why do you think that open questions are good in terms of learning?

R: Because I'm particularly interested in very bright kids, of which I teach a great deal, especially in this school. If I asked all questions of the Question type A I would've lost half the class. They would be snoring. So open questions let them follow their own ways of doing things which I really like. I would much prefer that as a question not an answer though.

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